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(54) **AEROFOIL.**

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Abbott, Von Doenhoff: "Theory of wing sections", Dover Publications, New York (US), pages 326, 327 see page 326, Naca 0021, columns 1,2 page 327, NACA 0024, columns 1,2, last but one line

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Description

This invention relates to aerofoils for wingsails.

Wingsails, used to propel marine or terrestrial vessels, generally require to be capable of operation on port or starboard tack. This may be achieved by having complex folding arrangements of asymmetrical aerofoils the camber of which can be reversed by extension and folding of separate sections. European patent specification 61291 describes a compound wingsail assembly that comprises a plurality of symmetrical aerofoil sections which can be angled with respect to one another to give cambered and slotted configurations. In that specification a trailing aerofoil is mounted for pivoting movement about a point on the chord of a leading aerofoil so that it can pivot from a coplanar position to angularly displaced positions.

The present invention relates to the particular profiles of aerofoil sections in a compound wingsail assembly of the type described in EP 61291.

According to the invention there is provided a compound wingsail assembly comprising a leading symmetrical aerofoil and a trailing symmetrical aerofoil mounted for pivoting movement about a point on the chord of the leading aerofoil from an aligned position coplanar with the leading aerofoil to positions angularly displaced from the aligned position, characterised in that the aerofoils have a thickness in the range of one to two fifths of their respective chord lengths, the leading aerofoil has a zone in which its thickness is at least 90% of its maximum thickness extending over substantially 30% of its chord length located in the range of 20% to 55% along its chord from its leading edge and the trailing aerofoil has a zone in which its thickness is at least 90% of its maximum thickness extending over substantially 20% of its chord length located in the range of 10% to 35% along the chord from its leading edge.

The invention is now described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic outline of an aerofoil according to the invention;

Figure 2 is a schematic outline of a slotted wing assembly according to the invention;

Figure 3 is a schematic outline of the wing of Figure 2 in a cambered configuration; and

Figure 4 is a schematic outline superimposing the aerofoil sections of Figures 1, 2 and 3.

Referring now to Figure 1, the aerofoil shown has a chord length C and a maximum thickness of 0.291 C, with a leading edge radius of 6.489% of C. The overall shape follows that of the table of ordinates Table 1.

TABLE 1

	% along chord	$\frac{1}{2}$ Width % of C	% along chord	$\frac{1}{2}$ Width % of C
	0	0	20	14.01
	0.5	2.66	30	14.54
	0.75	3.24	40	13.2
	1.25	4.28	50	10.74
	2.5	5.94	60	7.95
	5.0	8.27	70	5.22
	7.5	9.93	80	2.9
	10	11.13	90	1.1
			100	0

It will be seen from Table 1 that the maximum thickness occurs at approximately 30% along the total chord.

Referring now to Figure 2 the leading element 2 has a leading edge radius of 8.777% of its chord and a maximum thickness of 39.32% of its chord occurring at approximately 35% along the chord. The table of ordinates for this aerofoil shape is given in Table 2.

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TABLE 2

	% along chord	$\frac{1}{2}$ Width % of C	% along chord	$\frac{1}{2}$ Width % of C
5	0	0	35	19.661
	0.5	3.002	40	19.57
10	0.75	3.772	45	19.22
	1.25	4.88	50	18.52
	2.5	6.934	55	17.55
15	5.0	9.655	60	16.28
	7.5	11.586	65	14.728
20	10	13.34	70	12.973
	15	15.71	75	11.033
	20	17.42	80	8.865
25	25	18.6	85	6.618
	30	19.31	90	4.476
30			100	2.247

The trailing element 3 shown in Figure 2 has a leading edge radius of 10.625% of its chord with a maximum thickness of 30.42% of its chord occurring at approximately 25% along the chord from the leading edge. The table of ordinates for the profile is given in Table 3.

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TABLE 3

	% along chord	$\frac{1}{2}$ Width % of C	% along chord	$\frac{1}{2}$ Width % of C
5	0	0	45	12.0
	0.5	3.232	50	10.629
10	0.75	3.935	55	9.209
	1.25	5.044	60	7.789
	2.5	6.93	65	6.423
15	5.0	9.5	70	5.14
	7.5	11.19	75	3.92
20	10	12.488	80	2.87
	15	14.13	85	1.893
	20	14.98	90	1.082
25	25	15.21	95	0.473
	30	14.9	100	0
30	35	14.2		
	40	13.22		

The aerofoil of Figure 1 may be regarded as a basic member of the preferred family of wingsail profiles. It comprises a relatively high leading edge radius when compared with aerofoils for aircraft, and thickens relatively rapidly to reach a 90% thickness zone that commences at about 20% of the chord and continues to about 40% of the chord, the aerofoil then narrowing into the trailing portion and curvature undergoing an inflexion.

The second member of the family, aerofoil 2 of Figure 2, has a leading edge curvature that matches with the leading edge of the aerofoil of Figure 1, but is modified into a more abrupt trailing edge with almost no curvature from about two thirds of the way along the chord. In the drawing the trailing edges are flat, in a more general case they may only be substantially flat and may have a slight curve or a slight inflexion. If reference is made to Figure 3 it will be observed that the trailing edge of the aerofoil 2 is provided with a slat 4 which acts to extend the trailing edge. In practice the trailing edge of the leading section may be truncated for the pivot mounting of the slat. Although the curvatures of the leading parts of aerofoils 1 and 2 match, the positions of maximum thickness and leading edge radius in percentages deviate because of the differing lengths of the trailing sections. In Figure 4 the trailing edge modification is shown in dotted outline.

The trailing aerofoil 3 of Figures 2 and 3 has a fatter leading edge portion, but from the point of maximum thickness matches with the trailing section of the aerofoil of Figure 1. The relatively rapid rise to maximum thickness makes the point of maximum thickness occur relatively sooner along the chord. In Figure 4 the leading edge modification for a trailing aerofoil is shown in chain dot outline.

For a single aerofoil, the 90% thickness zone extends over a range of approximately 17% to 33% of the chord, most preferably in the range of 23% to 27% of the chord. The 90% thickness zone may commence in the range of 10% to 25% of the chord and be contained within the range of 10% to 55% of the chord from the leading edge, most preferably being within the range 17% to 45%. The maximum thickness may lie in the range of 20% to 40% but preferably is in the range of 25% to 30% of the chord. The leading edge radius is preferably in the range of 5.5% to 7.5% of the chord, but may be in the range 5.5% to 12%.

In compound wings the leading section (disregarding any flaps or slats) preferably has a shortened tail section with no inflexion so that the 90% thickness zone starts at about 19% to 23% of the chord. The trailing section of compound wings preferably has a leading edge radius that lies in the upper end of the range as defined for single aerofoils.

Table 4 gives the approximate preferred ranges in terms of chord % for the three wingsail aerofoils described above. In compound wingsails it is possible to modify the curvature at the end that is adjacent another aerofoil, or to modify the overall curvature and compensate in the other aerofoil.

TABLE 4

Foil	90% Zone range	90% Zone length	Max. Thickness position	Max. Thickness %	LE radius
1	17%—45%	25%	30%	29%	6.4%
2	20%—55%	30%	35%	39%	8.7%
3	10%—35%	20%	25%	30%	10.6%

Figures 2 and 3 represent an especially preferred compound wingsail according to the invention. The trailing element 3 is mounted on a boom or booms pivotable about an axis 5 on the chord of the leading element 2. Each of the main aerofoils 2 and 3 preferably have the same maximum thickness (although differing thickness is possible, the trailing section preferably having the larger thickness) of $.170 C_{TOT}$ where C_{TOT} is the total chord defined from the leading edge of the leading section to the trailing edge of the trailing section with the aerofoils aligned as in Figure 2. The leading element is shorter having a chord of $.432 C_{TOT}$ and the trailing section having a chord of $.560 C_{TOT}$ with a space of $.008 C_{TOT}$ between the aerofoils. The slat 4 has a length $.076 C_{TOT}$ and in the fully cambered position shown in Figure 3 is deflected through 25° with an adjustment facility of 5.5° . The preferred fully cambered configuration deflects the trailing section through 42° with the pivot of the trailing section positioned about $2/3$ of the way along the leading section: in Figure 3 is $.278 C_{TOT}$ from the leading edge.

A main upright pivot axis for the compound wing passes through the zone of the centre of pressure of the leading element 2 and the wing is trimmed to the wind by an auxiliary aerofoil, normally a tail vane, which also has an aerofoil section in accordance with the invention. As the tail vane is usually a single aerofoil and does not have slats or an adjacent aerofoil it preferably has the leading and trailing profiles shown in Figure 1.

Claims

1. A compound wingsail assembly comprising a leading symmetrical aerofoil and a trailing symmetrical aerofoil mounted for pivoting movement about a point on the chord of the leading aerofoil from an aligned position coplanar with the leading aerofoil to positions angularly displaced from the aligned position, characterised in that the aerofoils have a thickness in the range of one to two fifths of their respective chord lengths, the leading aerofoil has a zone in which its thickness is at least 90% of its maximum thickness extending over substantially 30% of its chord length located in the range of 20% to 55% along its chord from its leading edge and the trailing aerofoil has a zone in which its thickness is at least 90% of its maximum thickness extending over substantially 20% of its chord length located in the range of 10% to 35% along the chord from its leading edge.

2. A compound wingsail assembly according to claim 1 further characterised in that the leading and trailing aerofoils have the same maximum thickness.

3. A compound wingsail assembly according to claim 2 further characterised in that when coplanar the leading and trailing aerofoils have a combined chord length of C_{TOT} from the leading edge of the leading aerofoil to the trailing edge of the trailing aerofoil and the maximum thickness of the aerofoils is substantially $0.17 C_{TOT}$.

4. A compound wingsail assembly according to any preceding claim further characterised in that the chord lengths of the leading and trailing aerofoils are substantially in the ratio 43:56.

5. A compound wingsail assembly according to any preceding claim further characterised in that the leading aerofoil has a leading edge radius of substantially 8.7% of its chord length.

6. A compound wingsail assembly according to any preceding claim further characterised in that the trailing aerofoil has a leading edge radius of substantially 10.6% of its chord length.

7. A compound wingsail assembly according to any preceding claim in which the leading and trailing aerofoils are rotatable about a common axis and are arranged to be trimmed about that axis by an auxiliary symmetrical aerofoil, further characterised in that the auxiliary aerofoil has a zone in which its thickness is at least 90% of its maximum thickness extending over substantially 25% of its chord length located in the range of 17% to 45% along its chord from its leading edge.

8. A compound wingsail assembly according to claim 7 further characterised in that the profile of the auxiliary aerofoil follows the table of ordinates given herein as Table 1.

9. A compound wingsail assembly according to any preceding claim further characterised in that the profile of the leading aerofoil follows the table of ordinates given herein as Table 2.

10. A compound wingsail assembly according to any preceding claim further characterised in that the profile of the trailing aerofoil follows the table of ordinates given herein as Table 3.

Patentansprüche

1. Eine kombinierte Flügelprofilsegelanordnung mit einem vorderen symmetrischen Tragflächenprofilsegel und einem hinteren symmetrischen Tragflächenprofilsegel, das für eine Schwenkbewegung um einen Punkt auf der Profillehne des vorderen Tragflächenprofilsegels aus einer ausgerichteten Stellung koplanar mit dem vorderen Tragflächenprofilsegel in Positionen schwenkbar ist, die winkelmäßig von der ausgerichteten Position versetzt sind, dadurch gekennzeichnet, daß die Tragflächenprofilsegel eine Dicke in dem Bereich von ein bis zwei Fünftel ihrer entsprechenden Profillehnenlängen aufweisen, das vordere Tragflächenprofilsegel eine Zone besitzt, in der seine Dicke zumindest 90% seiner maximalen Dicke ist, die sich im wesentlichen über 30% seiner Profillehnenlänge erstreckt und im Bereich von 20% bis 55% längs seiner Profillehne von seiner Vorderkante liegt, und das hintere Tragflächenprofilsegel eine Zone besitzt, in der seine Dicke zumindest 90% seiner maximalen Dicke ist, die sich über im wesentlichen 20% seiner Profillehnenlänge erstreckt und im Bereich von 10% bis 35% längs der Profillehne von seiner Vorderkante liegt.
2. Eine kombinierte Flügelprofilsegelanordnung nach Anspruch 1, ferner dadurch gekennzeichnet, daß das vordere und das hintere Tragflächenprofilsegel die gleiche maximale Dicke besitzen.
3. Eine kombinierte Flügelprofilsegelanordnung nach Anspruch 2, ferner dadurch gekennzeichnet, daß das vordere und das hintere Tragflächenprofilsegel in koplanarer Ausrichtung eine kombinierte Profillehnenlänge von C_{TOT} von der Vorderkante des vorderen Tragflächenprofilsegels bis zur Hinterkante des hinteren Tragflächenprofilsegels besitzen und die maximale Dicke der Tragflächenprofilsegel im wesentlichen $0,17 C_{TOT}$ ist.
4. Eine kombinierte Flügelprofilsegelanordnung nach einem vorhergehenden Anspruch, ferner dadurch gekennzeichnet, daß die Profillehnenlängen des vorderen und des hinteren Tragflächenprofilsegels im wesentlichen zueinander im Verhältnis 43:56 stehen.
5. Eine kombinierte Flügelprofilsegelanordnung nach einem vorhergehenden Anspruch, ferner dadurch gekennzeichnet, daß das vordere Tragflächenprofilsegel einen Vorderkantenradius von im wesentlichen 8,7% seiner Profillehnenlänge aufweist.
6. Eine kombinierte Flügelprofilsegelanordnung nach einem vorhergehenden Anspruch, ferner dadurch gekennzeichnet, daß das hintere Tragflächenprofilsegel einen Vorderkantenradius von im wesentlichen 10,6% seiner Profillehnenlänge aufweist.
7. Eine kombinierte Flügelprofilsegelanordnung nach einem vorhergehenden Anspruch, bei der das vordere und hintere Tragflächenprofilsegel um eine gemeinsame Achse drehbar sind und angeordnet sind, um diese Achse mittels eines symmetrischen Hilfstragflächenprofilsegels getrimmt zu werden, ferner dadurch gekennzeichnet, daß das Hilfstragflächenprofilsegel eine Zone besitzt, in der seine Dicke zumindest 90% seiner maximalen Dicke ist, die sich über im wesentlichen 25% seiner Profillehnenlänge erstreckt und im Bereich von 17% bis 45% längs seiner Profillehne von seiner Vorderkante aus liegt.
8. Eine kombinierte Flügelprofilsegelanordnung nach Anspruch 7, ferner dadurch gekennzeichnet, daß das Profil des Hilfstragflächenprofilsegels der Ordinatentabelle gemäß Tabelle 1 folgt.
9. Kombinierte Flügelprofilsegelanordnung nach einem vorhergehenden Anspruch, ferner dadurch gekennzeichnet, daß das Profil des vorderen Tragflächenprofilsegels der Ordinatentabelle gemäß Tabelle 2 folgt.
10. Eine kombinierte Flügelprofilsegelanordnung nach einem vorhergehenden Anspruch, ferner dadurch gekennzeichnet, daß das Profil des hinteren Tragflächenprofilsegels der Ordinatentabelle gemäß Tabelle 3 folgt.

Revendications

1. Ensemble de voilure composite constitué d'une aile avant symétrique et d'une aile arrière symétrique propre à pivoter autour d'un point de l'axe géométrique correspondant à la profondeur de l'aile avant depuis une position coplanaire avec cette dernière vers des positions décalées également par rapport à la position alignée, caractérisé en ce que l'épaisseur des ailes est comprise entre un et deux cinquièmes de leurs profondeurs, l'aile avant comportant une zone dont l'épaisseur est d'au moins 90% de son épaisseur maximale sur substantiellement 30% de sa profondeur et disposée dans une plage de 20 à 55% de cette profondeur à partir de son bord d'attaque tandis que l'aile arrière est pourvue d'une zone dont l'épaisseur est d'au moins 90% de son épaisseur maximale et qui s'étend sur substantiellement 20% de sa profondeur et située dans une plage de 10 à 35% de cette profondeur à partir de son bord d'attaque.
2. Ensemble de voilure composite suivant la revendication 1, caractérisé en ce qu'en outre l'aile avant et l'aile arrière ont la même épaisseur.
3. Ensemble de voilure composite suivant la revendication 2, caractérisé en ce que lorsque ses voiles avant et arrière sont en position coplanaire, elles présentent une profondeur combinée de C_{TOT} à partir du bord d'attaque de la voile avant jusqu'au bord de fuite de la voile arrière, l'épaisseur maximale des voiles étant substantiellement $0,17 C_{TOT}$.
4. Ensemble de voilure composite suivant l'une quelconque des revendications précédentes, caractérisé en ce que les profondeurs des voiles avant et arrière sont substantiellement dans la rapport de 43/56.

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5. Ensemble de voilure composite suivant l'une quelconque des revendications précédentes, caractérisé en ce que le bord d'attaque de l'aile avant présente un rayon représentant en gros 8,7% de sa profondeur.

5 6. Ensemble de voilure composite suivant l'une quelconque des revendications précédentes, caractérisé en ce que le bord d'attaque de la voile arrière comporte un rayon représentant substantiellement 10,6% de sa profondeur.

10 7. Ensemble de voilure suivant l'une quelconque des revendications précédentes dont les voiles avant et arrière sont montées pivotantes autour d'un axe commun et sont prévues afin d'être orientées autour de cet axe par une voile symétrique auxiliaire, caractérisé en ce que cette voile auxiliaire comporte une zone dans laquelle son épaisseur représente au moins 80% de son épaisseur maximale, cette zone s'étendant sur substantiellement 25% de sa profondeur en étant disposée dans une plage de 17 à 45% de cette profondeur à partir de son bord d'attaque.

8. Ensemble de voilure composite suivant la revendication 7, caractérisé en outre en ce que le profil de la voile auxiliaire est conforme aux ordonnées du tableau 1 ci-joint.

15 9. Ensemble de voilure suivant l'une quelconque des revendications précédentes, caractérisé en outre en ce que le profil de l'aile avant est conforme aux ordonnées du tableau 2 ci-joint.

10. Ensemble de voilure suivant l'une quelconque des revendications précédentes, caractérisé en outre en ce que le profil de l'aile arrière est conforme aux ordonnées du tableau 3 ci-joint.

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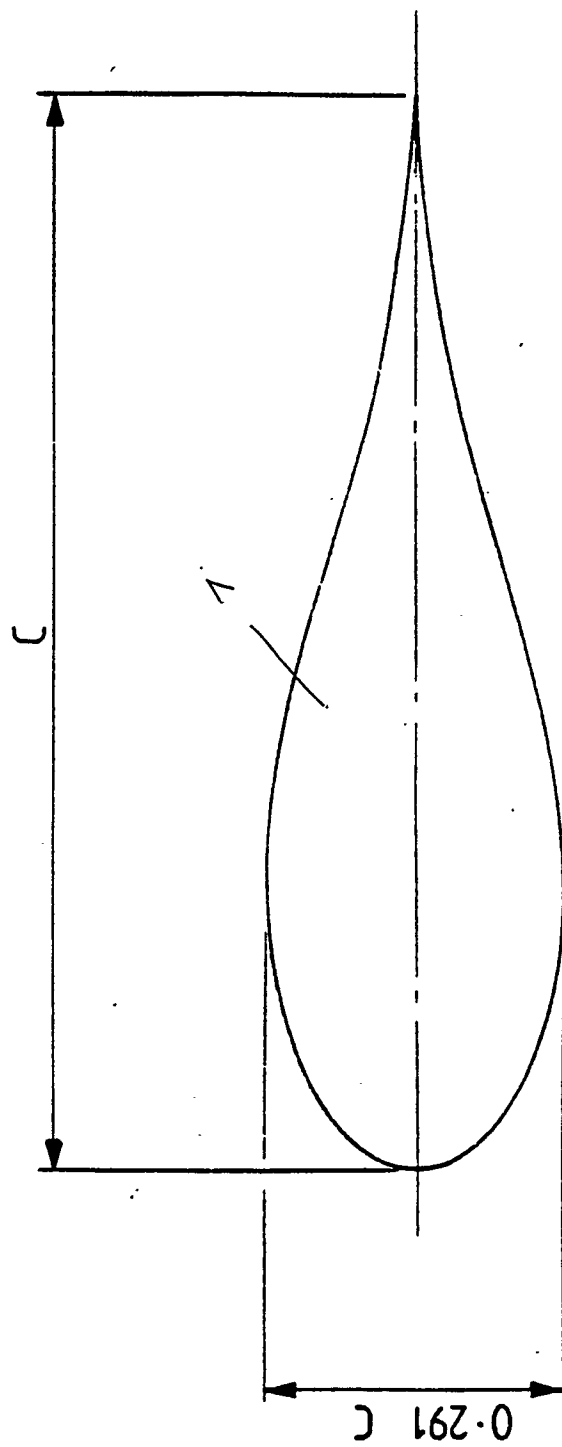


FIGURE 1

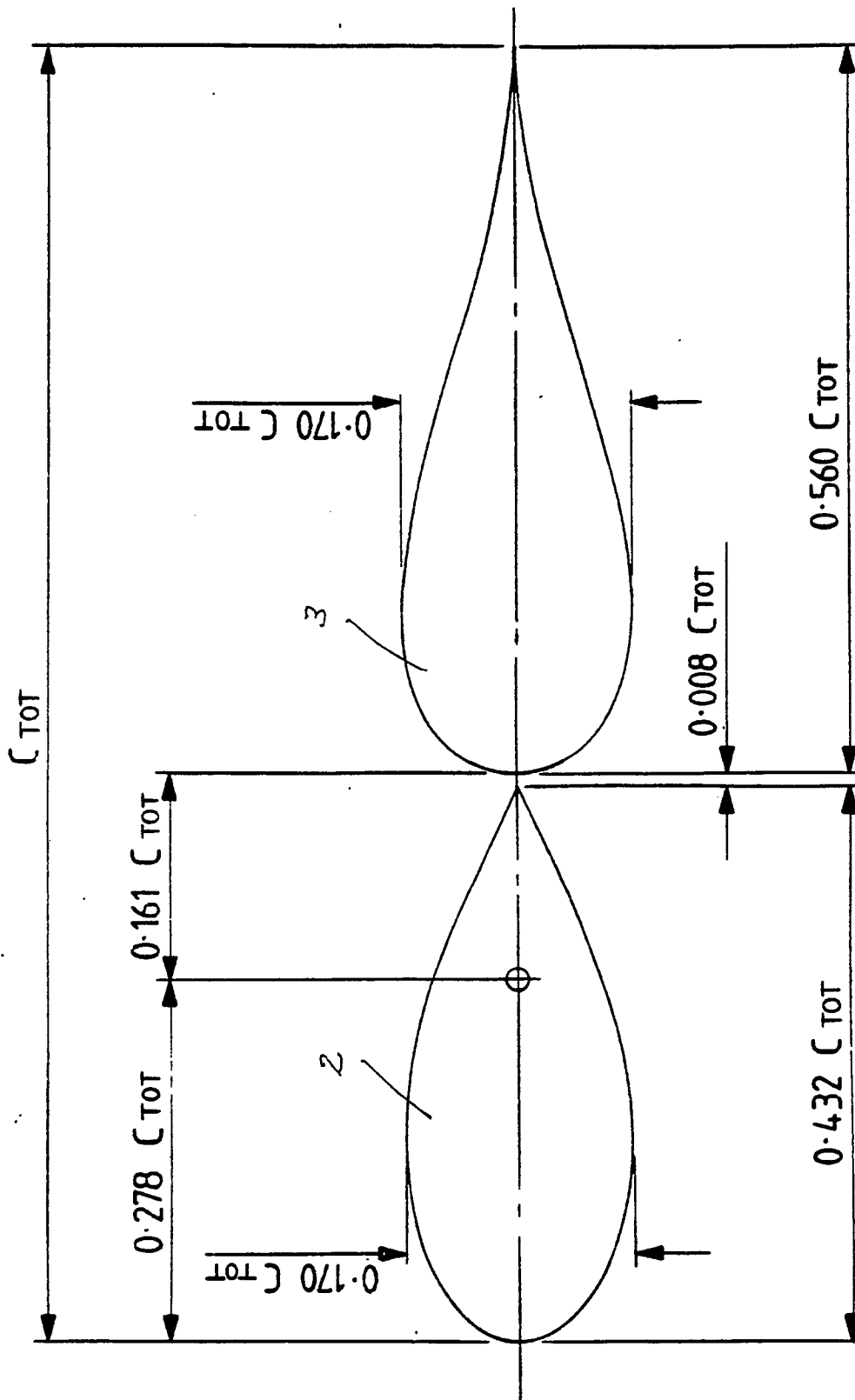


FIGURE 2

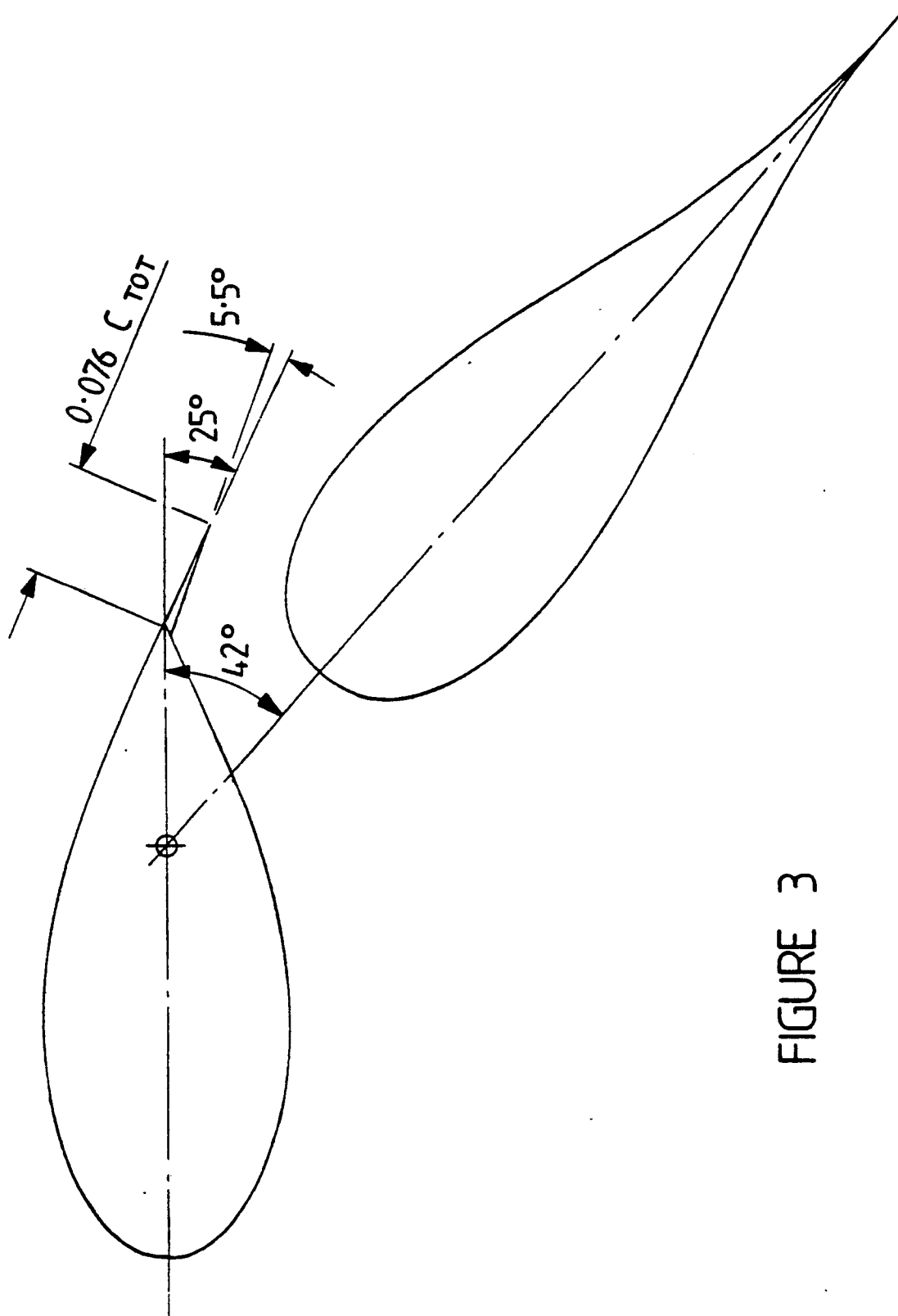


FIGURE 3

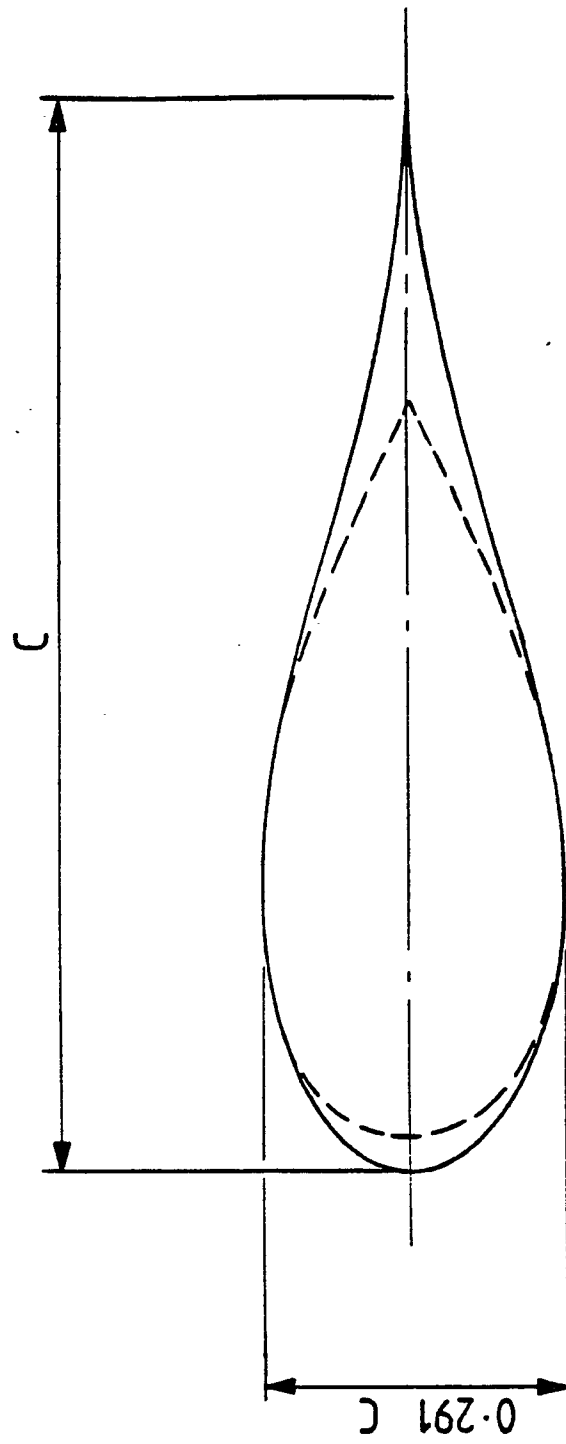


FIGURE 4